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FORTY YEARS OF DWARFMISTLETOE ON A PONDEROSA PINE PLOT NEAR QUINCY, CALIFORNIA

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With increasing pressures on the use and productivity of forest lands in the West there is a growing realization of the need for reducing the prevalence of dwarfmistletoes, recognized as among the most important sources of loss in western forests. Those concerned with the problem of control of these parasites, however, are confronted with a lack of trustworthy information on how to judge the impact of the parasites on infected stands under the various combinations of conditions encountered in the field and on how to appraise the economic feasibility of control measures. The problem is particularly difficult in ponderosa pine.

As a first step toward improving the background for judging such problems, Region 6 of the Forest Service and the Pacific Northwest Forest and Range Experiment Station have recently undertaken to work out study plans for obtaining the information needed. Because the problem is not confined to the Pacific Northwest, adjoining Regions and Stations are cooperating in the project to the extent possible.

A type of evidence that would be particularly useful but is almost entirely lacking consists in actual, long-time records of what has happened in specific sample stands infected with dwarfmistletoe. A 40-year record of the changes on one sample plot on the Plumas National Forest, California, presented in this report should contribute toward meeting this need. It is believed to constitute the longest record available in the West of the parasite and host status in a sample, mistletoe-infected pine stand.

In 1920 the San Francisco Office of Forest Pathology, Bureau of Plant Industry, established four study plots [1/] in dwarfmistletoe-infected second-growth ponderosa pine near Quincy Junction, Plumas County, California, on the Plumas National Forest. On three of them an attempt was made to prune out all visible infections of the dwarfmistletoe, *Arceuthobium campylopodum* Engelm. Plot 3 was reserved as an observation area to follow dwarfmistletoe development. Instead of pruning out infections they were left in place and tallied as to number and size in the course of a branch-by-branch inspection, in the course of which all except the small trees were climbed. Repeat examinations

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1/ The study was under the direction of the late E. P. Meinecke. H. G. Lachmund and the writer were responsible for the major part of the field work, with later participation by L. H. Daugherty, L. S. Gill, and Ernest Wright. R. F. Scharpf assisted in the 1960 relocation and reexamination of Plot 3.

and tallies were made in 1926 and 1933, after which the numbered tree tags marking all trees 3.6 inches and over d.b.h. in 1920 were removed and the plot was discontinued.

By 1960 the advantage of a long-time record of the incidence of dwarfmistletoe and its effect on the tree hosts on sample plots had become evident and a successful attempt was made to relocate Plot 3 of the Quincy Junction series. The original map showing the location of the individual trees on the plot could not be located but the survey notes from which the map had been drawn were still in the plot file, permitting a new map to be drawn. From this the remaining trees on the plot were located and identified on the ground. It was found that in the intervening years since 1933 a spur logging road had been run through the plot, resulting in the removal of four trees on the right-of-way, and a fifth live tree had been cut for some other purpose. Several relatively small black oaks on the plot had been cut for wood but otherwise the plot appeared not to have been disturbed.

OBJECTIVES AND DESCRIPTION

Objectives for Plot 3

The primary purpose of the plot was to follow the course of dwarfmistletoe infection on it for a period of years. Supplementary observations were made on the relation of strong, vigorous mistletoe shoot production to the amount of light received and to the thrift of the infected host part; also on the development of young infections in relation to host and surroundings. The results of these supplementary observations are not included in the present report.

The objectives did not include a determination of the effect of the parasite on the growth and mortality of the host trees or of effects on the stand, and for this reason no check plot in uninfected pines of comparable character was established. Likewise on this account, the breast-high diameter of the trees was not remeasured at the time of the plot reexaminations in 1926 and 1933.

General Plot Description

Location: NW 1/4, SE 1/4, Sec. 6, T24N, R10E, MDM, on moderate southwest slope above American Valley.

Elevation: 3,560 feet.

Soil: Compact, clayey, with pebbles and fragments of quartz, quartzite, limestone, and slate from the surrounding Calaveras formation.

Climate: Mean annual precipitation 40 inches, of which about 20 percent falls as snow. Temperature extremes approximately 98°F. maximum and -14°F. minimum.

Site: III (basis for determination limited; Show, Munns, and Dunning estimated the area as probably site IV in 1920).

Size: 0.226 acres.

Stand: Uneven-aged second-growth ponderosa pine with several intermingled black oaks and one large ponderosa pine overholder (died 1925). The oaks were cut for fuel during the 1950's.

Undergrowth: Negligible.

Duff and litter: Thin.

Ponderosa pines: 106, 1-inch d.b.h. and over (old ponderosa overholder not included in tally).

Dwarfmistletoe infection, 1920: All ponderosa pines on plot infected; 83 percent with one or more stem infections.

Source of dwarfmistletoe on plot

From appearances, most of the dwarfmistletoe present on the plot had its origin in two older infected ponderosa pines, one located about 10 feet inside the plot near the southerly corner and the other in the north central portion about 35 feet from the northeastern boundary. Some logging took place in the general area about 1870, and trees cut at that time may have contributed to the infection present. One of the two principal source trees had been dead for some years prior to plot establishment in 1920 and the other, near the southerly corner of the plot, died in 1925. After that time there were no infected older trees close enough to the plot to contribute to infection on it.

1960 reexamination

After reestablishment the plot was reexamined in September 1960. Because of limitations in time and equipment the trees were not climbed but were examined from the ground with the aid of field glasses. Many infections could no longer be distinguished individually, having grown together in the intervening years since the last examination and others could not be counted accurately from the ground. Numbers were counted where this was possible; otherwise numbers were estimated. The figures obtained are accordingly not directly comparable with those obtained in previous tallies except for stem infections, which are believed to be reasonably accurate for 1960, but they at least provide a rough measure of infection trends since 1933.

RESULTS

Dwarfmistletoe infections

All ponderosa pines on the plot were infected; the number of living infections tallied per tree in 1920 ranging from 1 to 215. All but six of the trees also bore dead infections in 1920, totalling 2,184 in number on the 106 trees present.

The highest number of living infections on the plot was tallied in 1926 (table 1), although both the median and mean numbers per individual tree continued to rise to a high in 1933. The mean values for infections per tree were quite strongly influenced by the high numbers of infections found on a few trees and for this reason the median values are more representative for infection on the plot than the means. It will be noted that the mean number of stem infections per living tree showed a gradual increase over the 40 years of observations, as can be expected from the fact that stem infections do not ordinarily die out as is the case with many of the twig and branch infections after varying periods of activity but remain alive until the tree dies unless eliminated sooner by top dieback.

Table 1.--Dwarfmistletoe infections, Plot 3, 1920-1960

Year tallied	Number of trees	Number of living dwarfmistletoe infections 1/					
		Total	Median per tree	Mean per tree	Total stem (bole)	Mean per stem-infected tree	Total witches' broom
1920	106	3,042	17	28.7	152	1.9	126
1926	96	3,475	20	36.2	188	2.3	103
1933	76	3,083	24	40.6	158	2.4	187
1960	2/ 39	1,186	23	30.4	87	2.6	(No record)

1/ Numbers of infections shown for 1960 not directly comparable with numbers for other years, except for stem infections (see text).

2/ Does not include five trees cut 1951-60 for road, etc.

The differences shown in total numbers of witches' broom recorded are believed not to be significant, as it was apparent from the records for individual trees that there was some difference in concept at the different examinations as to what constituted a broom. Because of this no tally of brooms was made in the 1960 examinations. From the tabulation below it will be seen that brooms were not an important factor on the plot.

	1920	1926	1933
Trees without brooms	59	62	31
Trees with 1 broom	23	18	17
Trees with 2-5 brooms	17	12	20
Trees with 5-10 brooms	7	2	4
Trees with over 10 brooms	0	2	4
Total trees	106	96	76
Total trees with brooms	47	34	45

The increase in numbers of infections on the plot between 1920 and 1933 as shown in table 1 took place in spite of a reduction in mean crown length from 26.4 feet to 23.2 feet, or a net length reduction of 12 percent from the 1920 lengths for trees still alive in 1933.

It seems probable that the crown reduction was principally the result of a series of years of subnormal precipitation (fig. 1) rather than solely from the effects of dwarfmistletoe. For the 11 seasons between July 1, 1922, and June 30, 1933, the cumulative deficiency in precipitation at Quincy, California, approximately 3 miles distant from the plot, amounted to 84.37 inches, the equivalent of more than 2 years of normal moisture. All six seasons before June 30, 1933, were deficient. Under these conditions a reduction in crown size and an increase in tree mortality were to be expected.

Not all trees showed increases in total living infections in examinations after 1920:

Period	Increased		Decreased		No change
	Trees	Infections	Trees	Infections	Trees
1920-1926	64	748	27	210	5
1926-1933	39	486	32	382	5
1933-1960	16	(?)	21	(?)	2

For the 1920-26 period, one-third of the increase in infections was in 3 trees. For the remaining 61 trees the average increase was 9 infections. Between 1926 and 1933 a third of the increase was likewise in 3 trees, the average for the remaining 36 being 8.7 infections per tree.

In 1926 and 1933 the sex of all living infections was recorded where determinable, with the following results:

	Male		Female		Sex not determinable	
	(Number)	(Percent)	(Number)	(Percent)	(Number)	(Percent)
1926	1,448	45.5	1,350	42.4	385	12.1
1933	892	32.7	955	35.0	883	32.3

The marked increase in the percentage of infections of undeterminable sex in 1933 as compared with 1926 is probably for the most part a reflection of the general poorer condition of the host trees in 1933 as a result of the preceding series of years of subnormal precipitation. For infections of determinable sex the figures for the 2 years indicate an approximate balance between sexes.

Effect of dwarfmistletoe on host

Changes in host thrift. At the time of plot establishment the apparent vigor or thriftiness of the host trees was rated in four classes: vigorous, thrifty, moderate, and poor. Surviving trees were again rated in 1933 and 1960. Assuming that the thrift standards remained approximately the same over the 40 years covered by the ratings, as we tried to make them, there was a gradual decline in thrift in the surviving trees on the plot (table 2).

Table 2.--Thrift ratings for dwarfmistletoe-infected ponderosa pines, Plot 3, 1920, 1933, and 1960

Thrift class	Percent of trees in class [1/] 1920	1933	1960
Vigorous	13	0	0
Thrifty	28	35	23
Moderate	42	36	38
Poor	16	29	38
Total	99	100	99
Trees in plot	104	72	39

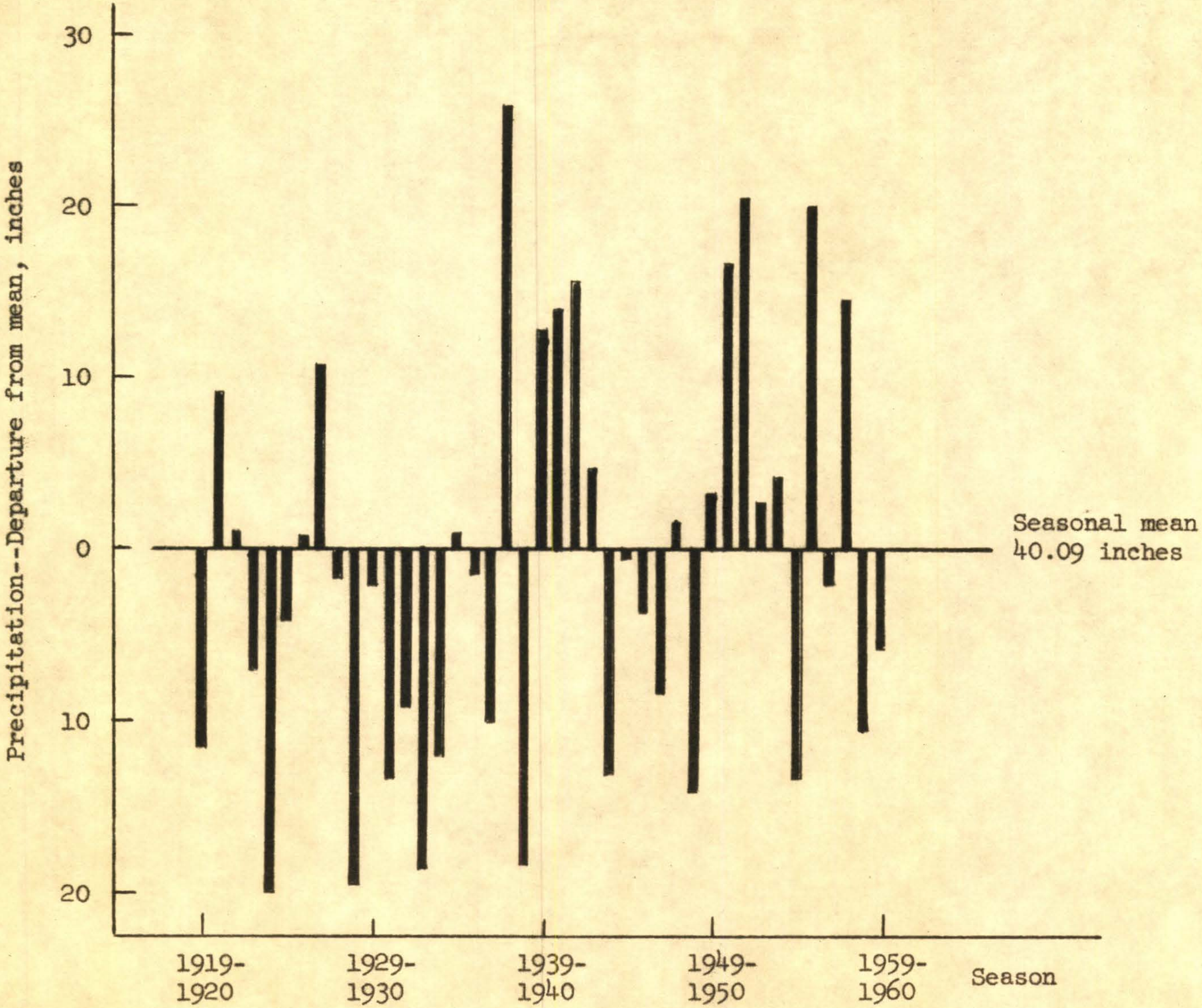

Figure 1.--Departure from long-time means of precipitation at Quincy, California, for seasons 1919-1920 to 1959-1960.

The change can also be expressed in terms of the number of trees passing from one thrift class to another or from a thrift class to dead between rating years (table 3). It will be noted that, with the exception of six trees which changed to a higher thrift rating during the two periods, all trees rated either remained in the same thrift class as before, retrograded in thrift to a poorer class, or died. During the two periods between ratings 69 percent of the trees rated declined to a poorer thrift class or died between 1920 and 1933, and 73 percent between 1933 and 1960.

Table 3.--Changes in thrift rating of dwarfmistletoe-infected ponderosa pines, Plot 3, 1920-1960

Rating change	Change in thrift-rating of trees for period 1/	
	1920-1933	1933-1960
	Number	Number
No change	25	17
Vigorous to thrifty	11	0
Vigorous to moderate	1	0
Vigorous to poor	1	0
Thrifty to moderate	12	9
Thrifty to poor	5	2
Thrifty to dead	2	5
Moderate to thrifty	4	1
Moderate to poor	11	10
Moderate to dead	15	8
Poor to moderate	1	0
Poor to dead	12	15
Total trees	100	67
Change to lower rating or dead, percent	70	73

1/ Four unnumbered trees rated in 1920 and still alive in 1933 were not rated in the latter year.

Growth and mortality of host trees

In the absence of a check plot uninfected by dwarfmistletoe for Plot 3, advantage was taken in 1960 of two control plots for thinning experiments in ponderosa pine young growth set up in 1920 near Plot 3 by S. B. Show, E. N. Munns, and Duncan Dunning of the Forest Service. These plots, designated as Plots D and E in the Quincy Junction thinning series, and now known as Plots 12 and 13, were located about 8 chains up the gentle slope from Plot 3 on a generally similar site. Differences in the character of the ponderosa pine stand and the degree of stocking among the plots are noted:

Plot	Size (Acres)	Age of trees, 1920 (Years)	Trees over 3.6" d.b.h. per acre (Number)	Trees under 3.6" d.b.h. per acre (Number)
D	0.438	56	900	810
E	0.536	45-57	840	2,350
3	0.226	45-125 (est.)	415	> 300

In 1947, Plots D and E were remeasured by members of the California Forest and Range Experiment Station and crop trees were selected. The plots were then divided into two subplots each, in such a way that an equal number of crop trees were in each subplot. One subplot of each pair was then thinned and the other left as a control. Half of the crop trees on both parts of each plot were pruned, up to one-third of the live crown being removed in the operation.

To make the control portions of these plots available for comparison with Plot 3 of the dwarfmistletoe study series, Region 5 of the U. S. Forest Service and the Plumas National Forest cooperated by remeasuring the trees on them in December 1960. 2/

Because of a few minor discrepancies in the records and the fact that the location of some of the trees dead for a long time could no longer be precisely determined, the figures for the control portions of Plots D and E in the comparison with Plot 3 in table 4 are probably not exact. However, any minor discrepancies present should not reduce the value of the overall figures for purposes of comparison.

2/ The remeasurements were made by R. Blomstrom of the Branch of Timber Management, Region 5, and John Ellison of the Supervisor's Office, Plumas National Forest.

Table 4.--A comparison of 1920 and 1960 tree data for the control portions of thinning plots D and E after division and for dwarfmistletoe Plot 3

Plot	Area	Trees 3.6' and over, 1920					
		Living		Dead		Basal area living trees	
		1920	1960	1920-1960		1920	1960
	Acres	Number	Number	Number	Percent	Sq. ft.	Sq. ft.
D, control	0.236	203	163	40	20	20.178	1/ 33.388
E, control	0.278	290	210	80	28	34.126	1/ 37.481
3	0.226	94	2/ 39	50	53	34.710	3/ 33.339

1/ Does not include slight ingrowth on Plot D and moderate ingrowth on Plot E. No ingrowth on Plot 3.

2/ Omits five trees cut or destroyed after 1950 for road, etc.

3/ Estimated as 35.283 with five cut trees included.

The most conspicuous difference between the thinning control plots and Plot 3 is the much higher mortality on the latter over the 40-year period of comparison, in spite of the much lighter stocking on it. In percent the mortality on Plot 3 is approximately double that on the other plots. There is also a lessened increase in basal area of living trees on the plot, even with the inclusion of estimated basal areas for the five live trees cut on Plot 3.

Loss of trees on Plot 3 was not uniform over the 40-year period but was heavier between 1926 and 1933 when the area suffered a series of years of deficient rainfall, as already mentioned.

Period	Span	Trees dead	Loss per year	Mistletoe infections on dead trees	1920 mean basal area of trees
	(Years)	(Number)	(Number)	(Mean number)	(Sq. ft.)
1920-26	6	10	1.7	12	.089
1926-33	7	20	2.9	25	.133
1933-60	27	32	1.2	39	.312

Also, the size of the trees lost, based on their 1920 diameters increased with the age of the plot. Early losses were confined to small trees, either intermediate or suppressed in dominance rating, with one exception. After 1933, however, the mortality included eight dominant (one co-dominant) trees that originally would have qualified as crop trees and that in 1920 had a mean basal area of 0.643 square feet per tree. Several of these were very heavily infected with dwarfmistletoe.

From the silvicultural standpoint total growth on an area is less significant than that of the trees chosen to be reserved for the final crop. On the control portions of Plots D and E, 22 trees on Plot D and 28 trees on Plot E were designated as crop trees at the time that the original plots were divided in 1947. Between that time and the time that the special remeasurement was made in 1960 one designated tree in each subplot died. In table 5 the growth of the surviving crop trees on these plots for the 1920-1960 period is compared with comparable trees still living on Plot 3.

It will be noted that the percent of increase in growth for both basal area and height on Plot 3 is intermediate between the corresponding percentages for uninfected Plots D and E. Without definite information on the ages represented on Plot 3, no accurate comparison can be made of this plot as against Plots D and E on basal area per acre but it is evident that Plot 3 does not suffer too much by comparison with the other two, especially in consideration of the fact that Plots D and E have been fully stocked, whereas approximately one-third of the area of Plot 3 was very poorly stocked when the plot was established and has remained so since then.

Relation of dwarfmistletoe infection to tree survival

During the 1933 examination on Plot 3 it was evident that the presence of dwarfmistletoe was not the primary determinant of mortality in part of the trees that had succumbed since 1926. As a measure of the incidence of the parasite in trees still alive on Plot 3 compared with the incidence in trees that died between 1920 and 1960, a compilation was made of dwarfmistletoe infections in the two groups. Because counts of individual infections in 1920, 1926, and 1933 showed that the number of infections present tended to diminish in trees in which the thrift rating had declined to poor prior to death, the highest number of infections recorded for the tree during the 40 years of observations was the one used in the compilations. In table 6 the living and dead groups of trees are compared.

Table 5.--Growth in basal area and height, 1920-1960, of designated crop trees still living in 1960 on subplots D and E compared with trees of similar character on Plot 3

Subplot of plot	Crop trees	Basal area, mean per tree: 1920	Basal area, mean per tree: 1960	Basal area, mean per tree: Increase	Basal area per acre, 1960	Height, mean per tree: 1920	Height, mean per tree: 1960	Height, mean per tree: Increase
	Number	Sq.ft.	Sq.ft.	Percent	Sq.ft.	Feet	Feet	Percent
D	21	0.309	0.478	54.7	42.56	1/ 30.7	41.2	34.2
E	27	0.243	0.448	84.3	43.50	2/ 28.1	42.4	50.8
3	20	0.683	1.181	73.0	3/ 66.51	47.9	66.3	38.4

1/ Based on 19 trees. 1920 heights not measured for all trees.

2/ Based on 17 trees. 1920 heights not measured for all trees.

3/ Includes mean basal area allowance for two crop trees cut on plot between 1950 and 1960 for road.

Table 6.--Comparisons between trees on Plot 3 alive in 1960 and those that died between 1920 and 1960

Tree group	Mean d.b.h., 1920	Trees in 4-6" d.b.h. class, 1920	Mean height per tree, 1920	Mean length of crown, 1920	Dwarfmistletoe infections: Mean total per tree	Dwarfmistletoe infections: Mean stem infs. per tree
	Inches	Percent	Feet	Feet	Number	Number
Living, 1960	9.6	15	42.8	29.1	49.7	2.3
Died, 1920-1960	6.5	62	31.9	19.7	43.5	2.6

It will be seen that both total height and crown length per tree as of 1920 were greater for the trees living in 1960 than for those that died during the 40-year period. Therefore the total number of infections as well as the stem infections had more lineal footage over which they might be distributed in the first tree group than in the second. Also a much higher percent of the trees that died were in the 4-6-inch d.b.h. classes.

To provide a more equal basis for comparison of numbers of infections per tree in the two groups the infections were converted to a 10-feet-of-crown-length unit for total infections per tree and to a 20-feet-of-total-height unit for stem infections:

Tree group	Mean infections per 10' of crown length	Median infections per 10' of crown length	Mean stem infections per 20' of tree height
	(Number)	(Number)	(Number)
Living, 1960	17.4	11.3	1.1
Died, 1920-1960	20.2	13.2	1.6

The differences in mean and median numbers of infections per 10 feet of crown length are not significant statistically although the numbers are slightly higher in each category for the trees that died than for those that lived. From these data we cannot say that the incidence of dwarfmistletoe infections has been a controlling factor in mortality on the plot. The number of stem infections per 20 feet of total height shows a larger proportional difference and from a

functional standpoint can be expected to have a greater influence on the growth capacity of the host tree than branch infections. By t test the difference is almost significant at the 5 percent level ($t=1.945$ vs. 1.990 at the 5 percent level).

The above comparisons are between infected populations: they do not provide a comparison between infected and uninfected groups, nor between trees with a high incidence and those with a low incidence of infection. Based on crop tree losses of one each during 13 years in the control portions of Plots D and E, the losses on Plot 3 should not have exceeded three potential crop trees in 40 years, taking into account that it is slightly smaller in area than either of the other two plots. Instead, losses on Plot 3 during the 40 years amounted to eight potential crop trees. It seems logical to assume that the difference represents the effect of the dwarfmistletoe present. All 8 trees had 1 or more stem infections, 2 had total infections of over 50 per 10 lineal feet of crown, and 4 had dropped from thrifty to moderate or poor in thrift between 1920 and 1933, including the 2 very heavily infected trees. It appears that dwarfmistletoe was probably a primary factor in the death of these four trees, with a basal area of 2.98 square feet. It may have been a factor in two additional cases.

GENERAL ASSESSMENT OF EFFECTS

Because of the absence of a control plot fully comparable to Plot 3 in 1920 except for the presence of dwarfmistletoe, the impact of the parasite on the plot cannot be closely assessed. However, the evidence points to the following generalizations:

1. The parasite has acted as a natural thinning agent, hastening the death of the smaller noncrop trees and approximately doubling the mortality rate in this class of tree as compared with that in uninfected stands. In this respect its action has been beneficial.

2. The net growth of potential crop trees has been reduced but not as yet to a marked degree. However, table 3 shows a gradual lowering in thrift rating of the crop trees on the plot at an age when vigor is normally well maintained or even increased. The only apparent reason for the decline appears to be the presence of the dwarfmistletoe. This gradual decline is likely to have a greater effect on growth as the trees become older than it appears to have had to date. Of the former potential crop trees still living on the plot, two are now in poor condition and may be expected to die within the next 10 years. They are 9 and 11 inches d.b.h. respectively.

3. The scattering young pine reproduction on the plot in 1920 was all infected and has since disappeared. In the absence of a strictly comparable control plot there is no positive evidence of what part the parasite may have played in the death of this young reproduction but from general experience the assumption can be made that it played some part, although competition for moisture was probably the

primary factor on that particular site. Newly established seedlings are negligible in number, and where present are mostly of other species, such as Douglas-fir. Indications are that few cones have been produced by the trees on the plot in recent years. This is in line with the effect reported by Korstian and Long (U.S.D.A. Bull. 1112, 1922) of reduced seed production by mistletoe-infected ponderosa pines in the Southwest.

Summarizing, although the presence of the parasite has apparently been beneficial as a natural thinning agent in intermediate and suppressed trees on the plot, the long-time effect for the stand as a whole has been detrimental. Growth of crop trees has not yet been seriously reduced but the general lowering of tree vigor on the plot suggests a more pronounced depressing effect on net growth as the trees become older.

THE QUESTION OF CONTROL

Although every tree on the plot was infected with dwarfmistletoe at the time the plot was established, the results to date do not indicate that control of the parasite during the 40 years covered by the observations would have been economically profitable. Control would have required the complete destruction of the stand at an age when very little of value could have been taken off in the process. In spite of the prevalence of the parasite the growth of crop trees to date has been reasonably good, as shown in table 5.

The general area was cut over lightly on a high risk basis about the mid-1950's, taking out scattered older overholders. Because of the general immaturity of the stands there, no regular harvest cutting is contemplated for some 35 years, but an intermediate cutting for purposes of thinning and stand improvement may be made about 15 years from now.

In outlining what appears to be a logical control program for the particular conditions represented by the stand on Plot 3, let us assume that no new control method for the parasite, such as the application of a differentially acting herbicide, will be developed in the near future, although such a possibility can by no means be ruled out. On the plot we have 20 potential crop trees, 2 of which are in poor condition and can be expected to die with 10 years. All but 3 of the remaining 18 are at present below acceptable merchantable size although many are approaching merchantability. Wood volume increment on the crop trees is still reasonably good for the site. Only 19 noncrop trees are left, of which 13 rate poor in thrift. Young reproduction is negligible.

Under these conditions the best program would appear to be:

(a) Defer consideration of dwarfmistletoe control until the time of the next cut.

(b) At the time of the next cut appraise conditions on the plot to see whether all marketable trees should be salvaged then and the rest destroyed or whether cutting should be deferred until the next succeeding cut.

(c) After salvage and the destruction of any remaining trees, regenerate the area by planting.

For infected stands differing in character from that on Plot 3 a control program should obviously be adjusted to the particular conditions prevailing on each.

APPLICATION OF PLOT RESULTS

Evidence is accumulating that site quality has a strong influence on the course of dwarfmistletoe development following the removal of an infected overstory. Climatic differences and racial differences in host susceptibility may also have an influence. For these reasons caution should be used in assuming that any conclusions reached from the Plot 3 records will apply directly to *Arceuthobium campylopodum* on ponderosa pine elsewhere. The chief value of the results should be as a check against assumptions concerning the effects of dwarfmistletoe under conditions comparable to those on Plot 3.